High-Resolution Hydrographic Surveys near the Shelfbreak in the East China Sea: Joint Studies with National Taiwan University

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LONG-TERM GOALS

Our long-term goal is to understand shelfbreak processes in the vicinity of the Cold Dome northeast of Taiwan and to quantify the impact of oceanographic processes on the uncertainty of prediction of low frequency acoustic propagation in this area. This work is part of the Quantifying, Predicting, and Exploiting Uncertainty DRI.

OBJECTIVES

The scientific objectives this past year were to execute a pilot study to establish baseline oceanographic and acoustic propagation conditions as a prelude for the main field program. During August/September, 2008, we successfully made oceanographic measurements in Taiwan Strait, east of Taiwan northward of the Ilan Ridge, and in the Cold Dome over the outer continental shelf in collaboration with Taiwanese scientists led by Dr. Jan Sen of National Central University.

APPROACH

We performed high-resolution hydrographic surveys at the shelfbreak in the East China Sea near North Mien-Hua Canyon. In collaboration with Professor Joe Wang of National Taiwan University, we used the National Taiwan University SeaSoar, a towed undulating vehicle, to do long (40 km) cross-shelf and along-shelf sections to examine variability on scales important for low-frequency acoustics (1-10 km). In addition, we deployed two thermistor chains and a bottom-mounted ADCP to measure high-frequency motions for five days (the cruise was shortened by two days due to Typhoon Sinlaku).

WORK COMPLETED

We successfully completed three surveys of the shelfbreak. The first survey was a 15 km square centered on the shelfbreak (Figure 1) to demonstrate that we could successfully operate over the steep and rugged topography of the upper continental slope. The second survey consisted of two intersecting cross-shelf and alongshelf sections in order to establish scales of variability and to define oceanographic features that might affect transmission loss. An important part of the sampling strategy was close coordination with acousticians on board. Mobile acoustic sources were deployed by OASIS Inc. (K. Heaney, D. Morton, and C. Emerson) along the transects immediately after completion of the SeaSoar runs so that we can use the environmental data in propagation modeling of transmission loss. Dr. Chi-Fang Chen of National Taiwan University also deployed a vertical line array from the ship during the acoustic sampling. During the cruise, P. Lermusiaux of MIT provided ocean circulation forecasts and we in turn supplied data for assimilation into his numerical model of the flow fields near Taiwan.

In addition, G. Gawarkiewicz served as the US coordinator of the field program and was in close communication with a number of Taiwanese scientists before the cruise to coordinate operations between three different ships.

RESULTS

Despite having limited temporal and spatial coverage, we identified a number of interesting and important cross-shelf exchange processes. Figure 2 shows the Temperature/Salinity properties of the water masses from the first SeaSoar survey. The warm, fresh water mass in the upper left portion in the figure is the water mass exiting Taiwan Strait to the north. The cold saline water mass in the lower right portion is Kuroshio water. Note that there are two different mixing lines between the Kuroshio water and the Taiwan Strait water. The lower mixing line is the water comprising the Cold Dome, while the upper mixing line represents Kuroshio water which penetrated onto the shelf.

A front oriented across the isobaths appeared in the sections (Figure 3 for temperature and Figure 4 for salinity). Note in Figure 3 the upwards sloping isotherms near the intersection point between the cross-shelf and alongshelf section. In addition, the deeper waters offshore, between 100 and 200 m depth, were warmer in the eastern sections relative to the western section. The near-bottom salinities over the shelf within the intrusion were 34.8, indicative of core Kuroshio water within the intrusion. Note that the launch point for the mobile acoustic sources was near the intersection point between the long cross-shelf and long along-shelf sections and so we should be able to identify the impact of the Kuroshio intrusion front on the transmission loss as the analysis proceeds.

Finally, further onshore over the shelf we identified the Cold Dome (Figure 5). This is the region in the cross-shelf section where the thermocline is quite shallow. The offshore edge of the Cold Dome is in close proximity to the Kuroshio intrusion front.

Another interesting result was the extremely steep slopes and rugged topography of the upper continental slope. This presented interesting challenges in terms of safely towing the SeaSoar. We anticipate that this rough topography may also lead to a multitude of generation spots for internal waves and thus an unpredictable internal wave field with regard to arrival times.
Gawarkiewicz has completed a technical report on the science plan for the QPE DRI (Gawarkiewicz, 2007). We have also recently submitted a manuscript (Linder et al., 2008) on the seasonal hydrographic structure and mean transports in Taiwan Strait.

IMPACT/APPLICATIONS

The environmental data collected here will be extensively analyzed in collaboration with acousticians and numerical modelers of ocean circulation. The integrated physical oceanographic measurements with the mobile acoustic source/receiver data on transmission loss is important in providing the field testing of the Predictive Probability of Detection (PPD) methodology developed by Abbot et al. (2006). The data will also be used to evaluate uncertainty in the circulation model used by P. Lermusiaux. In addition, we have had extensive technical exchange with National Taiwan University, National Central University, and other Taiwanese research groups with the SeaSoar operations, ADCP processing, and integrated oceanographic/acoustic sampling strategies.

RELATED PROJECTS

This project is related to Integrated Oceanographic and Acoustic Studies in the South China Sea, a project which also is a joint effort with National Taiwan University. In that project we are analyzing previously collected field data and relating the oceanographic variability to the observed changes in transmission loss. We are working closely with P. Abbot of OASIS Inc., along with Professors J. Wang and C. Chen of National Taiwan University on that project. This project also relates to the Persistent Littoral Undersea Surveillance/Innovative Naval Prototypes Program in that we are applying previously developed sampling strategies and integrated Seasoar/mobile acoustic source/sonobuoy sampling to determine the temporal and spatial structure of transmission loss in shelfbreak regions.

REFERENCES

Abbot, P., I. Dyer, and C. Emerson, 2006. Acoustic propagation uncertainty in the shallow East China Sea. J. Oceanic Eng., 31, 368-383.

PUBLICATIONS

Linder, C., G. Gawarkiewicz, J.-H. Tai, and T.-Y. Tang, 2008. A Seasonal Climatology of Taiwan Strait and the northeastern South China Sea. J. Geophys. Res.-Oceans, Submitted.

G. Gawarkiewicz, 2007. Science Plan for the Quantifying, Predicting, and Exploiting Uncertainty DRI. Technical Report, Woods Hole Oceanographic Institution.

FIGURES

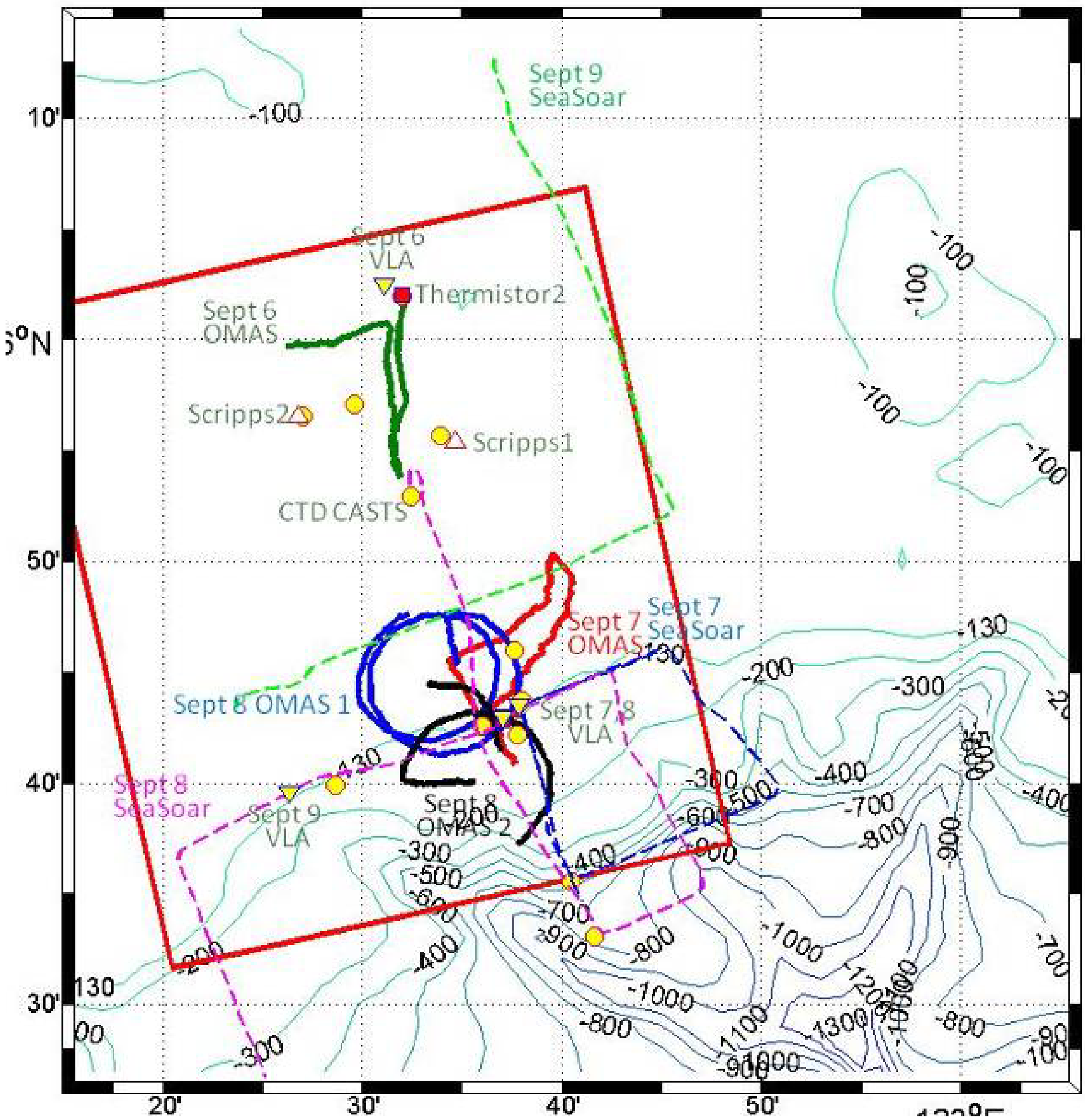

Figure 1- An overview of the observations made during the QPE Pilot Cruise on the Ocean Researcher I in September, 2008. The SeaSoar tracks are marked by the dashed lines and the solid lines denote OASIS Inc. Mobile Acoustic Source tracks. CTD casts are marked by the yellow dots and moorings are denoted by triangles.

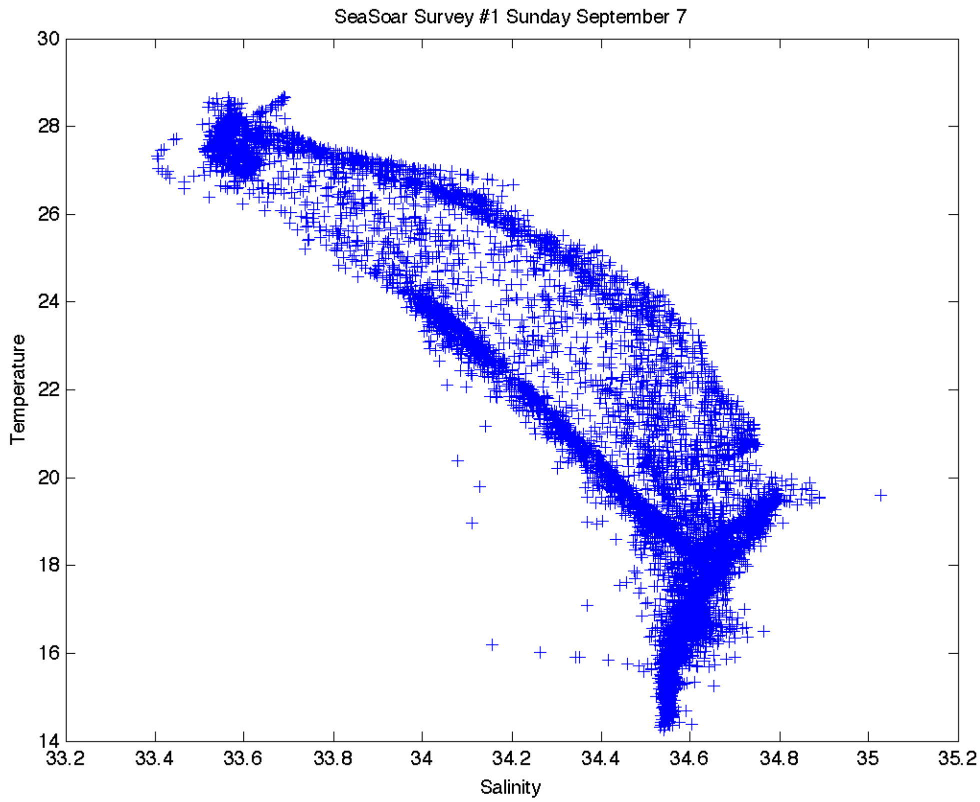

Figure 2- The Temperature/Salinity distribution for the SeaSoar data collected during the first survey. The cluster of points at the maximum temperature and minimum salinity is associated with the water mass from Taiwan Strait, while the cool water with high salinity is the Kuroshio water. The upper mixing line between these two main water masses represents Kuroshio water on the shelf while the lower mixing line includes water masses of the Cold Dome.

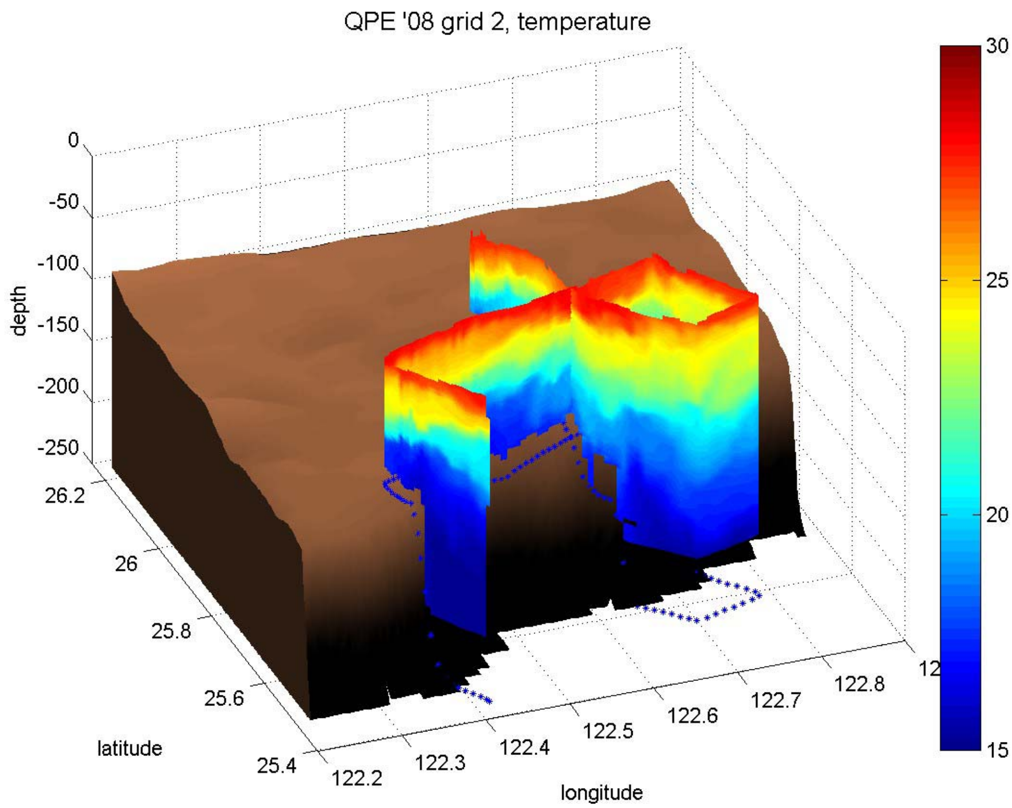

Figure 3- A projection of the SeaSoar transects of temperature from the second survey. The view is to the northeast.

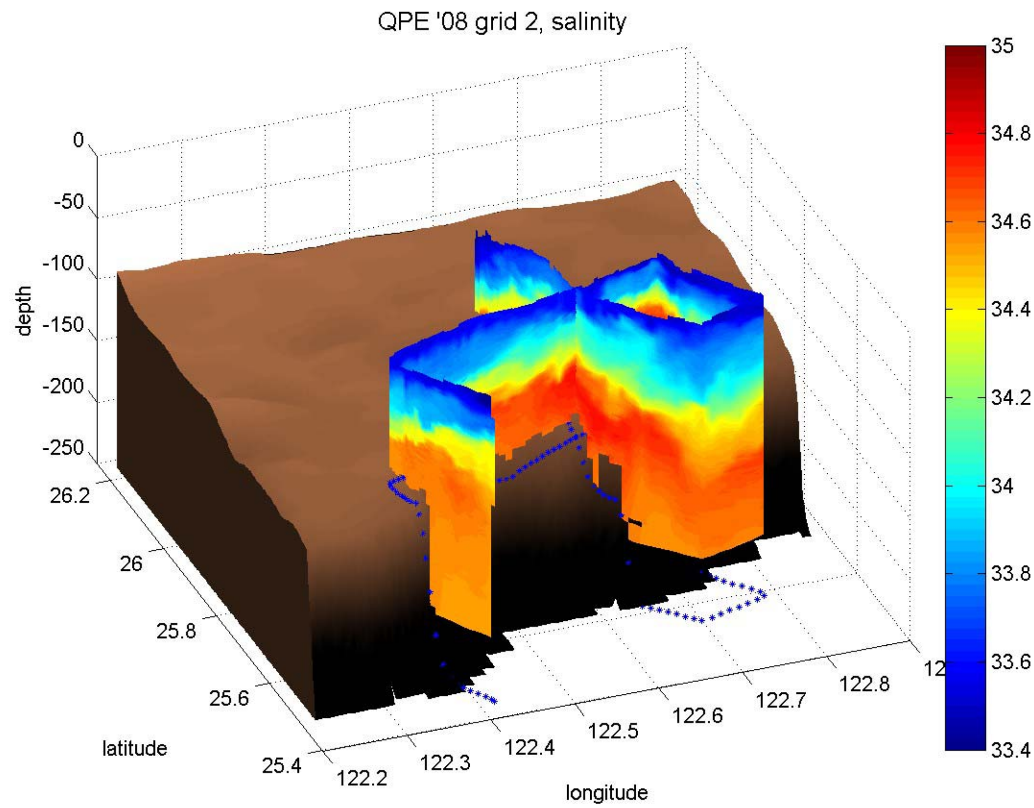

Figure 4- A projection of the SeaSoar transects from the second survey showing the salinity field.

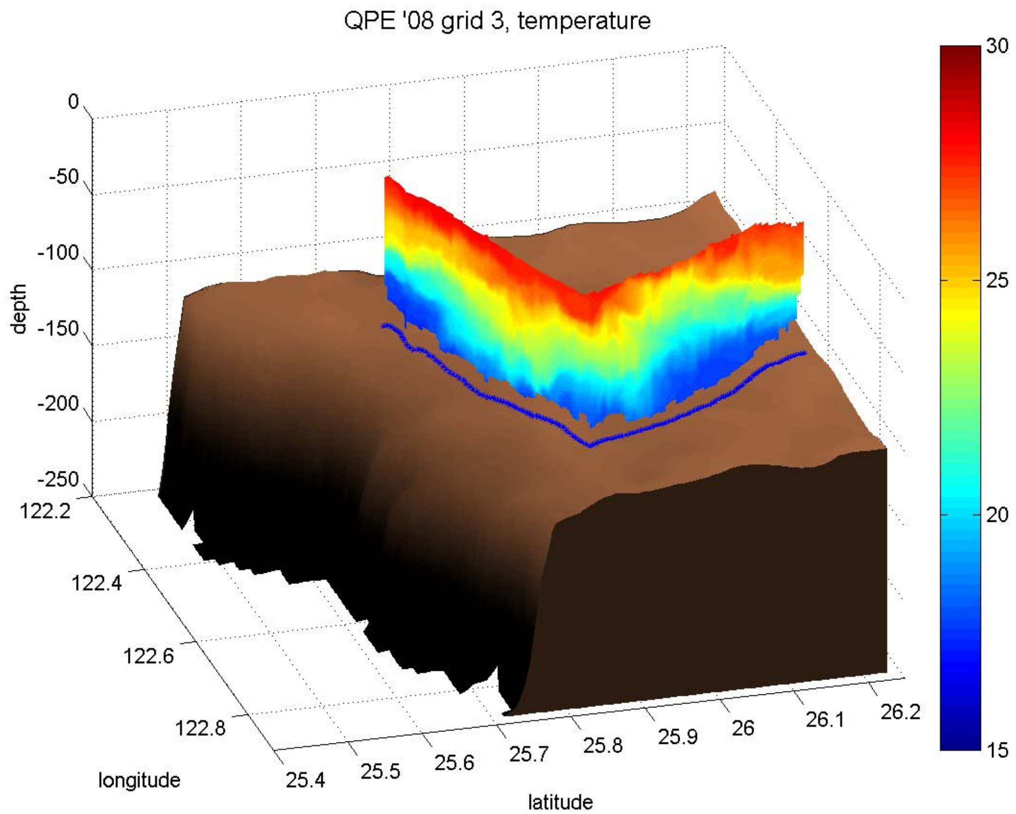

Figure 5- A projection of SeaSoar transects of temperature from the third survey, located further shoreward on the shelf. The Cold Dome appears in the cross-shelf section as the area with the doming thermocline and the thick cold bottom layer.